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Advanced Visualization in Solar System Exploration and Research (ADVISER)
Principal Investigator: James W. Head, III

Summary of Research (10/15/04 – 10/14/08)
NASA Grant NNG05GA61G

Background

The objectives of this research were to both advance space science knowledge and research advanced visualization tools for space science and education by integrating and extending the state-of-the-art in hardware and software technologies. Our three-pronged science approach (understanding Mars polar evolution, Mars tropical glaciers, and Noachian Hydrological Cycle) wove together our strengths in planetary geoscience with the basic NASA research and exploration theme for "Follow the Water" for Mars, providing scientifically credible direction for tool research and scientific discovery. Personnel from the Department of Geological Sciences and the Center for Computer Visualization have worked together to develop these new tools for simulated planetary surface exploration and research. We feel that the results of this very productive synergistic relationship have greatly enhanced and advanced our research capabilities as well as provided "fieldwork" opportunities for hundreds of undergraduate students.

Following is an explanation and justification for this research, a list of accomplishments, and a bibliography highlighting presentations and publications of this work. We would like to add that the work is continued in a follow-on grant. (Three members of our research team, James Dickson, Andy Forsberg, and John Huffman, presented this work in a new (for us) venue, the i3D Conference in Boston, earlier this month, where they were awarded the Bronze medal [3rd place for Best Poster presentation]).

Geologists explore the Earth primarily through fieldwork and analysis of the geological record at various points on the surface of the Earth. They then integrate these individual points of understanding about the Earth's surface through more synoptic analysis, often aided by the integrating perspectives seen from image and topographic data acquired from Earth orbit. Decades of field experience by the PI on volcanic eruptions, the Earth's sea floor, and in the Antarctic Dry Valleys have shown this to be the case and how this perspective can be augmented by helicopter or remote-operated vehicle perspective.

Planetary geoscientists commonly work toward an understanding in the reverse order. The distances and times involved dictate that the first data from individual moons and planets comes from flybys and orbital spacecraft, perhaps in some cases evolving towards the deployment of a few landers and rovers, and for the Moon, human explorers. Now that we have global data sets for the Moon, Mars, and Venus, comprehensive regional data sets for many of the outer planet satellites, and very recently obtained global data for Mercury (thanks to the MESSENGER Mission), we can begin to undertake the detailed exploration of planetary surfaces that is required for the full understanding of the evolution of planets.

How do we accomplish this? Fortunately, developments in advanced computation, visualization, and immersive virtual reality environments have created the ability to place

the geoscientist back down on and near the surface to visit virtually any part of the planet they wish to see, and to regain the perspective that is the foundation for the understanding of the geological relationships necessary to unlock the record of the history of the planets.

This work extends the state-of-the-art in advanced visualization tools for solar system exploration, provides educational tools for teaching planetary science, reports results from user studies on the efficacy of our ideas, and lays the groundwork for achieving longer term goals beyond the scope of this proposal.

Relevance to NASA

These efforts help to fulfill the fundamental goals and objectives of the NASA AISR Program, and address the major goals of NASA as an Agency, including the President's Exploration Initiative.

Relevant technologies: Interactive 3D terrain visualization with very large data sets (high resolution topography, image and related data); telepresence; telecollaboration.

Current Applications

1. Science Analysis:
 - Analysis of Mars North Polar deposits and layering, strike/dip measurements, climate change implications.
 - Analysis of Mars dichotomy boundary major degradation processes.
 - Analysis of structure and morphology of tropical mountain glaciers.
 - Analysis of Mars Volcanic Edifices
 - Analysis of Antarctic Dry Valley Field Sites and Polygon Analysis
 - Incorporating GIS databases into 3D visualization for the Antarctic Dry Valleys and on Mars
2. Mission Planning:
 - NASA/JPL North Polar Reference Design Mission (Palmer Quest) traverses.
 - NASA Mars Scout ARES Mission proposal for low altitude airplane overflight launched in 2011: Developed reference traverse overflights.
3. Teaching at the Undergraduate and Graduate Level:
 - Geology 16: Freshman seminar "Exploration of Mars" (21 students).
 - Geology 5: "Earth, Moon and Mars" (~300 students).
 - Geology 291: "Problems in Mars Climate History" (10 students).
 - Geology 292: "Problems in Antarctic Geoscience" (5 students).
4. Demonstrations:
 - Illustrating concepts and capabilities to interested parties and visitors [DOE (LANL, ORNL); NASA (GSFC, JSC, JPL, LaRC, HQ); NOAA (NCAR); Brown; RISD; IBM; Discovery Channel "The Planets", etc.].

Accomplishments

1. Imported and visualized multiple data sets: MOLA altimetry, Viking, MOC, THEMIS and HRSC image data sets,
2. Imported Mars GCM simulation data. Worked with researchers from LMD, France on visualization of scalar and vector data such as ice-mixing ratios and wind velocities.
3. Placed 25 geoscientists and engineers (faculty, JPL, graduate students) on the surface of Mars to address scientific problems.
4. Conducted laboratory exercises for ~300 undergraduate students in the Cave environment. The system was used by students to explore and understand specific regions on Mars. (see references)
5. Developed important aspects of the Field Kit (field location, strike and dip determination, instant altimetry and profiles, traverse recording, etc.) and provided the geoscientists with these tools in the IVR environment.
6. Developed ancillary field instruments (e.g. virtual photography, virtual GPS, and the PDA field notebook) and are providing geoscientists with these tools in the IVR environment.
7. Developed Web-based portal service to enable geoscientists to transfer data back and forth from their conventional desktop working environments.
8. Integrated ROAM 2 rendering system into IVR environment; built toolkit on top of it.
9. Developed support for non-immersive desktop system.
10. Integrated ArcMap to formalize the initial correlation of data sets for enhancing data preparation for importing to immersive environment.
11. Developed tablet PC: Integrated pen-based user interface with immersive visual terrain.
12. Evaluated Wacom Cintuiq tablet based system for mapping tasks.
13. Processed the entire HRSC L1 image database on a parallel cluster. Resulting products were imported easily into ArcGIS and enabled faculty/students to continue with analysis of this high resolution dataset.
14. Developed new techniques to combine high-resolution HRSC topography datasets with precise MOLA measurements. (see references)
15. Developed interactive image processing techniques to enhance display and interpretation of conventional images. (see references)
16. Produced New Science Results for Mars (see references).
17. Applied to NASA/JPL North Polar Mission Design (Palmer Quest).
18. Applied to Antarctica field season planning and post-trip analysis of datasets.
19. Completed and submitted Education and Public Outreach proposal.
20. Wrote paper ADVISER: Immersive Scientific Visualization Applied to Mars Research and Exploration” outlining our plans and results for Photogrammetric Engineering & Remote Sensing special issue on Mapping Mars.
21. Wrote paper “ADVISER: Immersive field work for planetary geoscientists” for IEEE CG&A special issue on GeoVisualization. The paper examines several application scenarios for the system and the benefits of using an Immersive VR environment.

Current Capabilities

1. Interactive fly-through (30+ stereo fps) of 8k x 8k DEM.
2. Import data through ArcMAP
 - MOC, THEMIS, HRSC images.
 - MOLA topography.
3. Import and display of General Circulation Model simulation data.
 - Streamlines of wind data
 - Preliminary visualizations of ice-dust mixing ratios
4. Field Kit and Virtual Field Instruments:
 - Many capabilities developed.
 - Queries (elevation, dip/strike, terrain profiles, etc.)
 - Compass, Lat/Lon, Traverse Planner and Traverse Map.
5. Cave and desktop user interfaces (on Linux)

Upcoming Plans

1. Incorporation of the IVR facility for an Engineering course on mission design.
2. Integration with navigation system: How to plan for field work and establish traverse planning highlights with ArcInfo in order to optimize the planned input to the IVR facility.
3. Support all tool functionality in both Cave and desktop versions of ADVISER.
4. Evaluate relative value of Cave and desktop ADVISER tools for science tasks
5. Add animated particles visualization of wind data in GCM visualizations
6. Develop data management solutions for 'out of core' data sets.
7. Develop techniques so that large data sets have low impact on interactivity (high frame rate and low latency).
8. Continue debriefing by users.
9. Complete Education and Public Outreach proposal and submit.
10. Extend to three additional science themes and topics.
11. Explore for next proposal: initial mechanisms for tele-collaborative viewing within Brown.
12. Explore for next proposal: initial mechanisms for tele-collaborative viewing outside of Brown at NASA and with other users.

Tracking

1. Undergraduate university students filled out forms on their use and analysis of the facility and made suggestions for improvement.
2. Graduate students have discussed and described their experiences with students and faculty with all IVR facility personnel in attendance. More detailed reports are underway.

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3. Interested undergraduates are doing hands-on work to be sure that the latest 'video-game-like' rapid response controls are properly considered.

Application to NASA and Missions Programs

1. Palmer Quest, a NASA Nuclear Mission Design Study in conjunction with the NASA Jet Propulsion Laboratory. The facility was used to site landing sites on the North Polar Cap of Mars, to design traverses with the companion rover, and to verify design and traverse trafficability and capability.
2. Developed airplane traverses for ARES Mars Scout Proposal.
3. NASA Office of Space Science research programs as described above.
4. NASA Astronaut Candidate Training: -Using for site selection and traverse planning for a human reference mission to Mars for broad concept certification and NASA Astronaut training. Will use for the moon when Lunar Reconnaissance Orbiter data are available.

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